



Grand Challenge Area

Nanoscale Processes for Environmental Improvement

Challenge

Pollution has long been recognized as a serious threat to both the local and global environments and to our quality of life. The development of new technologies that enable industrial economies without harming human health and the environment is of critical importance in the 21st century. Development of innovative technologies for manufacturing, transportation, and other activities that reduce or eliminate the production of harmful by-products, or for treatment and remediation of existing toxic substances in the environment, presents major challenges for our society.

Vision

Nanoscale science and engineering can significantly improve our understanding of molecular processes that take place in the environment and help reduce pollution by leading to the development of new “green” technologies that minimize the use, production, and transportation of waste products, particularly toxic substances. Environmental remediation will be improved by the removal of contaminants from air and water supplies to levels currently unattainable, and by the continuous and real-time measurement of pollutants. In addition, increasing knowledge of the environmental, social, and human health implications of nanotechnology is crucial.

In order to understand the consequences of contaminants moving through the environment, interdisciplinary research is needed on molecular and nanoscale processes that take place at one or more of the interfaces or within nanoscale structures in natural systems. Such research includes studies of inorganic/inorganic, inorganic/organic, and organic/organic interfaces, with a focus on the specific processes dominated by small length

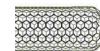
scales. Separation science—exploiting the evolving capability to tailor nanostructured membranes—offers new opportunities to selectively extract contaminants from air, water, and soil.

Novel interdisciplinary research that adapts newly developed experimental, theoretical, and computational methods for characterizing nanostructures is needed. The community of scientists and engineers studying the fundamental properties of nanostructures must be connected with the community attempting to understand complex processes in the environment in order to hasten the integrated understanding of the environmental implications of nanoscale phenomena.

Agency Participation

(leads in bold)

- DOE** Extraction of radionucleotides from otherwise benign materials
- EPA** Detection, remediation, and prevention of environmental pollution
- FDA** Ensuring safety and security of the food chain
- NSF** Nanoscale processes in nature, “green” manufacturing
- USDA** Agriculture technologies for minimizing environmental footprints, pollution remediation, precision agriculture, carbon sequestration



**Research Example:
Treatment of Contaminated Groundwater
with Iron Nanoparticles (supported by EPA
and NSF)**

Researchers at Lehigh University recently found that nanoscale particles of metallic iron could potentially play a large role in the remediation of contaminated groundwater (Figure 15). Interaction between iron and the pollutant trichloroethylene (TCE) results in the degradation of TCE to more environmentally benign products. Palladium or platinum is added to the nanoparticles to enhance the rate at which this reaction takes place. The researchers carried out a field demonstration at an industrial site in which nanoparticles injected into a groundwater plume containing TCE reduced contaminant levels by up to 96%. A wide variety of contaminants (including chlorinated hydrocarbons, pesticides,

explosives, polychlorinated biphenyls, and perchlorate) have been successfully broken down in both laboratory and field tests. The potential for remediation stems from the high reactivity of the nanoparticles and the fact that the technology is portable and highly scalable. The high reactivity of these particles can be attributed to their extraordinarily large surface area ($\sim 33.5 \text{ m}^2/\text{g}$). With an average particle diameter of less than 100 nanometers, the particles are injectable and can be delivered to contaminant hot spots or source areas as needed. This work is currently being funded by EPA to explore its potential in treating hazardous waste. The technology is being tested at several Federal and industrial sites for soil and groundwater remediation.

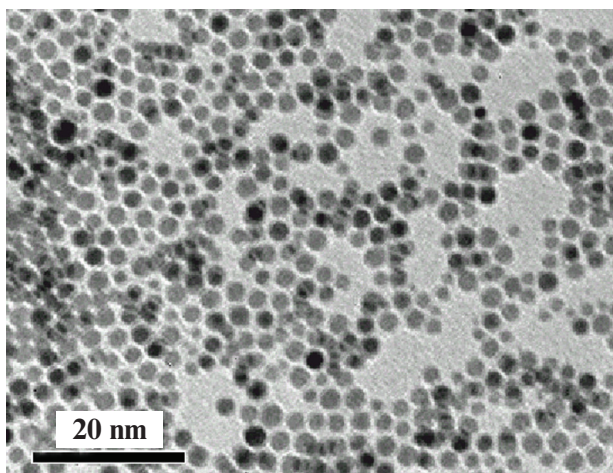
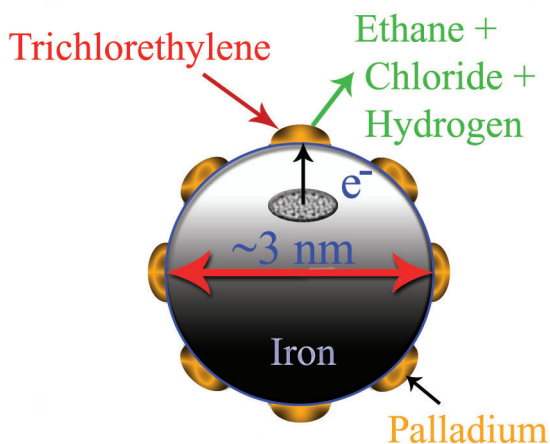


Figure 15. Schematic depiction of the remediation process in which iron nanoparticles transform a contaminant (trichloroethylene) in water into more environmentally benign products. In the process shown on the left, elemental iron acts as an electron (e^-) donor while trichloroethylene serves as the electron acceptor for the chemical reaction. The presence of palladium metal on the surface of the iron nanoparticles enhances the transformation. The right portion of the figure shows an electron microscope image of the iron nanoparticles (courtesy W. Zhang, Lehigh University).